"Spheres of Reality": A Conceptualization of Desktop Virtual Environments in Career and Technical Education and an Implementation Training Model

Lynna J. Ausburn, *Oklahoma State University*
Floyd B. Ausburn, *Oklahoma State University*

Abstract

With the development of sophisticated computers and digital imaging systems, virtual reality (VR) technologies and virtual environments (VEs) can now bring expanded learning options and benefits to the desktop at feasible costs. However, a six-year research program in desktop VR for CTE at Oklahoma State University has demonstrated that to take full advantage of the benefits of screen-based VE training, learners require considerable pre-immersion training. This paper discusses issues in preparing learners to successfully experience desktop VEs. It introduces a conceptualization of these VEs as spheres, worlds, and universes of reality, and offers a training model for preparing learners for virtual experiences in CTE. Application of the conceptualization and training model presented here may help optimize VE technology and extend its effectiveness and uses in CTE programs that benefit from immersive experiences for students before they enter today's complex, expensive, and often dangerous working environments.

Virtual Environments in CTE and Industry

> Where would you like your students to explore today? Inside an airplane cockpit, a prototype care, a submarine, or a computer? How about an operating room in a large metropolitan hospital, a late-night emergency response location on an isolated country road, an upscale merchandising outlet in Tokyo, a construction site in New York City, an agricultural experimental station in India, a cutting-edge biotech laboratory in Germany, or a crime scene in Los Angeles? (Ausburn & Ausburn, 2008, p. 43)

Instructors in career and technical education (CTE) frequently wonder "how to go there" to help their students discover, explore, and understand a variety of working environments that can be difficult, expensive, dangerous, or even impossible to experience in the physical world. Today, a new generation of virtual technologies can remove the walls of traditional classrooms and dramatically expand the ability of CTE educators to take their students "on location." A considerable body of research has reviewed virtual reality (VR) and virtual environments (VEs) and has generally concluded these technologies have strong potential for technical, professional, and workplace education (Ausburn & Ausburn, 2004, 2008a, 2008b; Ausburn, Ausburn, Cooper, Kroutter, & Sammons, 2007; Ausburn, Martens, Dotterer, & Calhoun, 2009; Riva, 2003; Watson, 2000). This conclusion is supported by the fact that many occupations and industries as diverse as medicine and emergency response, dentistry, surgical technology, biotechnology, aviation and space exploration, marine exploration, welding, equipment design, construction, law enforcement, crime scene investigation, firefighting, vehicle prototyping, lathe operation, hazard detection, high-risk driving, mining, railway operations, automotive spray painting, nuclear energy, and heavy equipment operation have reported successful use of VEs in delivering

effective and cost-efficient ways to train and work (Ausburn & Ausburn, 2008; Ausburn et al., 2007).

New high-fidelity, photo-real "desktop" VR technologies use sophisticated digital imaging and interactive user-controlled interfaces to create screen-based virtual learning environments. These new desktop VEs are especially promising for CTE because they put the motivational benefits of virtual reality on standard desktop and laptop computers with financial and technical levels that are feasible for most institutions and instructors. In addition to being cost-effective, realistic, and engaging, these new screen-based VEs allow risk-free practice and mastery of dangerous skills and environments (Ausburn & Ausburn, 2008; Bollman & Friedrich, n.d.). They are conceptually and functionally close media kin to computer-based games (Isdale, Fencott, Heim, & Daly, 2002) and often possess similar motivational properties derived from their learner-controlled interactive game-like interfaces (Bollman & Friedrich). Important for CTE, VEs have also shown good potential for transfer of training to real-world work (Bollman & Friedrich). These characteristics suggest that desktop virtual reality can be an important technology for CTE and workforce training.

Theoretical Foundation for Virtual Environment Effectiveness: The "Presence" Construct

Several approaches have been used to identify reasons underlying the effectiveness of virtual environments as an instructional technology. The explanatory approach taken early in VR research by Winn et al. (1997) was based on the properties of learner immersion in, and active interaction with, a learning environment in their proposal that three factors contribute to the success of VR technology: (a) immersion, (b) interaction, and (c) engagement and motivation. Selwood, Mikropoulos, and Whitelock (2000) proposed that the power of VEs lay in their ability to activate the intellectual, social, and emotional processes of learners. Seth and Smith (2004) related the interactivity of VR to human experience and tied its effectiveness to its ability to let learners interact personally with a location. They also addressed the technical properties of VR, supporting its ability to provide depth cues through stereo imagery to help convey to learners three-dimensional spatial relationships accurately and realistically. Virtual reality developer Sunrise VR (2010) cited the media properties of the technology as motivational, pointing to its combination of the power of a computer, the information of an encyclopedia, the imagery of a movie, and aspects of real life to create a powerful learning experience. Ausburn and Ausburn (2008b) proposed a "supplantation/concreteness hypothesis" relating the effectiveness of VR to its ability to overtly combine and present many visual details simultaneously and its visual fidelity in depicting physical reality.

The most compelling and complex foundation for VR/VE effectiveness – and the most extensively discussed in the literature – is a theoretical construct generally referred to as "presence," a phenomenon that seems to occur when many attributes of virtual reality come together effectively. The presence phenomenon is so complex it is the subject of entire journals and a major international professional society. The International Society for Presence Research (ISPR) firmly ties presence (shortened from "telepresence") in virtual systems to human-made technology or "mediation," and defines it officially as:

> … a psychological state or subjective perception in which even though part or all of an individual's … experience is generated by and/or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience. Except in the most extreme cases, the individual can indicate correctly that s/he is using the technology, but at *some level* and to *some degree* her/his perceptions overlook that knowledge and objects, events, entities, and environments are perceived as if the technology was not involved in the experience. (International Society for Presence Research, 2000)

Less formally, presence generally refers to a user's sense of "being there" in a virtual environment, the illusion of "non-mediation," (ISPR, 2010; Lombard & Ditton, 1997), or the sense in users that they have actually *been somewhere* instead of just seeing it (Di Blas & Poggi, 2007; Mikropoulos, 2006). Riva (2009) recently uncoupled presence from the notion of overcoming mediating technology and focused instead on the significance of producing in VEs a sense of agency and control by users through support of their personal actions and intentions. Taken together, these definitions perhaps suggest that presence is essentially the perceived "reality" in virtual reality.

The construct of presence and the understanding of when users in virtual environments are "present" offer substantial technical, physical, psychological, and social difficulties. More than a decade of intensive research from the viewpoints of numerous academic disciplines has still not resolved these issues or clearly defined presence or its assessment in evaluating virtual environments. Spagnolli, Lombard, and Gamberini (2010) recently pointed to the complexities of research on virtual environments created by issues in operationalizing and achieving presence; measuring the nature and intensity of presence; the roles and interactions of media form, content, and user characteristics in the emergence of presence; and assessing the power of presence to affect outcomes in the real world. While these research issues are formidable, virtual reality researchers must continue to address them if the technology is to mature as an instructional strategy. Lombard, Ditton, and Weinstein (2009) supported the need for continued research to confirm and better understand the achievement and effects of presence. They identified several important effects of presence, including improved skills training and task performance – an effect of particular importance in evaluating VEs for CTE.

The current state of research on VEs and on the nature, role, creation, and effects of presence in VE experiences leads to the conclusion that VR researchers are well aware that presence exists and is a critical issue in attempts to understand this technology. However, it is not yet clearly understood what creates presence; how to measure it; what technology tools and techniques best foster it; how individual task and learner characteristics interact with it; or how to measure its effects on learner outcomes, performance, and transfer of training. At this point, VR researchers know presence can be "there" and is a critical feature in VR effectiveness, but we don't fully understand this phenomenon and its impacts.

A research team in the Occupational Education Studies program at Oklahoma State University has been working with desktop virtual environments in CTE for six years. Through small-scale experimentation, we have learned a great deal about this exciting technology and its

potentials for technical training. We have also developed an acute awareness of the presence construct in VR and its illusive nature. Like other researchers focusing on this technology, we have answered a few questions about presence and left many others unresolved. This situation provided the impetus for this paper. The paper presents what we have learned about presence in using desktop VR in CTE programs; a conceptualization of presence based on the notion of "spheres of reality;" and a proposed approach to helping users understand this "sphere" concept through preparatory training prior to a VR encounter.

"Spheres of Reality": A Conceptualization of VEs for CTE

Six Critical Components for Successful Desktop VEs

The Virtual Reality Research Team at Oklahoma State University has invested six years in researching desktop virtual environments in technical and occupational education, and summarized key findings from this research in a recent paper (Ausburn, et al., 2010). Several critical discoveries from our VR research are relevant to the present discussion. These include six major components for VE designers, implementers, and learners:

(1) *Instructional design of desktop VEs*: Design aspects such as learner entry into the virtual scene, orientation cues, navigation devices, and software controls are critical for learning and are far more difficult and complex in nature than we initially understood.

(2) *Interface and navigation designs and technologies and learners' familiarity and comfort with them:* These technical elements are crucial for learning success and are difficult to accomplish successfully. Poor-quality, confusing, or difficult user/software interfaces frustrate learners, destroy the reality/presence of a VE, and result in poor motivation and learning performance. Not only do poor interface designs and technologies cause distracting software manipulation and control problems for learners, they also exacerbate difficulties in orientation, wayfinding, and navigating in virtual spaces. Hunt and Waller (1999) asserted that "Orientation is our awareness of the space around us, including the location of important objects in the environment" and that "A person is oriented when he knows his own location relative to other important objects in the environment, and can locate those objects relative to each other" (p. 4). For Blade and Padgett (2002), orientation was how people determine where they are, where they came from, and where they want to go. Darken and Peterson (2002) pointed out the orienting and navigating difficulties inherent in VEs, stating that:

> All VEs that simulate a large volume of space will have navigation problems of one sort of another. Typically, any space that cannot be viewed from a single vantage point will exhibit these problems as users move from one location to another. The need to maintain a concept of the space and the relative locations between objects and places is essential to navigation. This is called *spatial comprehension,* and like verbal comprehension, involves the ability to perceive, understand, remember, and recall for future use. (p. 494)

Many VEs appropriate for CTE are extensive and complex spaces and are subject to learner problems in orientation, wayfinding, and navigation. We have observed many times in our studies a “lost in space” phenomenon experienced by learners in our desktop VEs and have learned that it is extremely difficult to devise software techniques and interfaces that lessen these problems. It has proved equally difficult to devise training that improves learners’ familiarity and comfort with VE software interfaces and controls.

(3) *Sense of virtual environments as complete and complex learning spaces:* For learners to successfully orient in a VE, navigate easily within in, and develop a sense of presence about it, learners must understand that a VE is a complete “world” to be carefully and systematically explored. This is particularly difficult to achieve in desktop VR where the learner’s visual field is limited to a standard computer screen. This is one of the most difficult and perplexing problems we have encountered in using desktop VR, and we have come to believe it must be addressed through extensive learner training. This problem is addressed in detail below in the discussion of the “spheres of reality” concept.

(4) *Clear explication of learning purpose and tasks:* Qualitative data from our experiments have demonstrated that learners must have thorough comprehension of learning purpose and tasks *before* entering a VE. Comments from research participants such as “I didn’t understand why I was looking at this program or what I was supposed to do,” “I wish I had known what I was looking for,” “This activity is fun, but I don’t know why I am doing it,” and “If I had known what I would be tested on, I would have explored entirely differently” have made it clear that learners cannot become immersed in a VE or learn from it effectively unless they understand the learning tasks and goals of a virtual exploration before they experience it. Despite several efforts at clarifying learning goals to learners through basic instructions to them, the Oklahoma State University studies have not yet succeeded in accomplishing this critical task. This has led us to conclude that understanding of learning tasks and goals should be part of extensive pre-immersion VE training for learners.

(5) *Technical quality:* The necessity for a high level of technical quality is clear in the body of current VR research and in our own experience. Without technical quality such as image detail and clarity, smooth zoom and pan capability, and seamless “stitching” of multiple images into smooth panoramas, VEs cannot achieve visual and physical “fidelity,” defined by Waller, Hunt, and Knapp (1998) as the extent to which a VE and interaction with it are indistinguishable from a real environment, and similarly by Blade and Padgett (2002) as the degree to which a VE duplicates the sensory stimulation and the look and feel of operational equipment of the simulated context.

(6) *Adequate training and practice before exposure to virtual environments:* The Oklahoma State University research on desktop virtual environments in technical applications has clearly demonstrated that learners must have extensive training and practice in orienting and navigating in a VE, and in efficiently manipulating the software features and controls, *before immersion occurs* on the computer screen. After considerable experimentation, we have concluded that these processes are much more difficult, take much longer to master, and require far more thorough and systematic learner training than we anticipated. Thus, we assert that pre-immersion learner training in understanding and using screen-based VEs in

CTE must become the focus of more research and development, and we plan to address this issue as we move forward with our VR research agenda.

While it is difficult to accomplish these six key components in desktop VEs, their successful realization is critical if a sense of presence is to be realized by learners. It has been our experience that the loss of presence through failure in these six elements results in poor immersion by learners, loss of interest and motivation, and weakened learning performance. We have observed this repeatedly in our VR experiments and have documented it in performance test scores and in dozens of qualitative comments from our research participants and our researchers.

A Conceptualization of Desktop Virtual Environments for CTE: "Spheres of Reality," Virtual Worlds, and Virtual Universes

Attainment of presence in VEs is particularly important in training for CTE programs. To successfully mirror physical environments, facilitate transfer of training, and prepare learners properly for working realities, virtual experiences must: (a) have accuracy and fidelity, (b) create a sense of immersion, and (c) help students gain deep understanding of the real-world situations in which they must work. "Being there" in experiencing Shakespeare's Globe Theater or the Amazon rainforest is interesting and appealing; it is *critical* in learning to function quickly, safely and correctly in an emergency responder crisis, a high-risk manufacturing shop, a medical emergency, a chemical hazard situation, or a terrorist/hostage negotiation.

To promote presence in CTE virtual environments and obtain their learning benefits, the authors propose that an on-screen VE can be conceptualized as a "sphere of reality" in which learners are personally immersed and over which each individual has personal control in exploration and discovery. In the sphere of reality concept, learners must come to understand they are not just *viewing* an environment on their computer screen, but rather are *standing in the center of a spherical space*. The details of the space are all around them in 360 degrees horizontally and perhaps vertically as well. The sphere is a complex and multi-dimensional experiential and learning domain that replicates a real-world space; it is essentially a self-contained repository of realistic experience and information, much like a visual library. Within this sphere of reality, learners have individual control of how they choose to explore, understand, and master the environment in which they are immersed. The situation is analogous to sitting in a car that is located in the center of a 360° space. The car's occupant can only see part of the space at any time through the windscreen, but by moving the car in a circle, can come to see the entire space and all information within it. This movement is accomplished in desktop VEs by using the mouse to pan left and right to explore the entire 360° space just as if the learner was walking around or turning head or body inside a room or other space. In addition, learners in a sphere of reality can simulate walking toward or away from parts of the scene by using the zoom in and out navigation function.

The Oklahoma State University VR research program has clearly demonstrated that getting learners to understand this sphere of reality concept, feel immersed in a screen-based VE, and experience it viserally – e.g., gain a sense of presence – is quite difficult. The first requirement is a high level of technical quality and fidelity in creating the VE imagery. This has been difficult to achieve until recently. However, new digital cameras and desktop VR software

can now create excellent visual detail, photo realism, seamless stitching of individual images into clean panoramas, and user-friendly navigation – all of which are essential for creating presence at the desktop. While a high level of technical quality is vital in creating presence in desktop spheres of reality, it is not sufficient in itself to accomplish this job. Another important element in creating sensory and operational fidelity in the sphere is creating an accurate and complete mirror of the real-world environment that is modeled. This entails careful selection of items to be included in the VR sphere and accurately showing their spatial and functional relationships. Hunt and Waller (1999) alluded to the role of preservation of key visual and operational content in a true simulation in their assertion that in a simulation, as opposed to a simple representation, similarity is maintained between the representation medium and the important attributes of what is represented. Finally, appropriate, sufficient, and systematic *training of learners* to understand the sphere of reality concept, to comprehend their learning tasks and goals as they explore the sphere, and to correctly orient, wayfind, and navigate within the sphere is crucial. Our research has shown that adequate learner training is more difficult and takes much longer than we anticipated. Learner training requirements are addressed below in a proposed training model.

The sphere of reality and successful training to enter it in a CTE program become even more difficult when it is realized that a desktop virtual environment may not be either simple or isolated. Rather, an individual sphere may be part of an entire CTE curriculum, and that curriculum may contain simple or complex individual VE spheres and even a set of interlinked or stand-alone spheres. A way to conceptualize and to identify or name the components of such a VE schema is to think in term of micro, meso, and macro curriculum components. In this schema, one can think of individual on-screen environments as spheres of reality. These micro "spheres" can be either stand-alone or linked by navigational controls to related spheres. The spheres can be parts of a wider meso-size "world" of reality that are interrelated by common aspects of content. "Worlds" can in turn be parts of a macro virtual "universe" that represents all virtual components in a course or curriculum. This conceptualization is illustrated in Figure 1 which shows an example from a CTE curriculum in surgical nursing.

Learner Functioning in Reality Spheres, Worlds, and Universes

For learners to function efficiently and effectively in desktop VR spheres of reality, they must understand numerous things about the on-screen virtual space in which they are placed. First they must understand the nature and orientation in which they "enter" an on-screen VE. When they open a desktop VR panorama, learners essentially enter a type of VE typically known as a "first person VE," described by Schroeder (1997) as an on-screen experience in which users view and interact with a simulated 3D world from their own personal observer point of view, moving and exploring by using a mouse to simulate what they would do in physical reality. Ausburn and Ausburn (2008b) described screen-based first person VEs as VR panorama "movies" in which learners have complete navigational control and select for themselves where, when, and how to explore rather than having these choices made in advance by a videographer. When learners open such a VE, they are standing at the center of a complex space, with objects and information all around them. This is what Hunt and Waller (1999) called an "egocentric" frame of reference that is centered on the leaner. Starting from this centered, egocentric spatial reference point, learners in a sphere of reality must continuously orient, wayfind, and navigate in

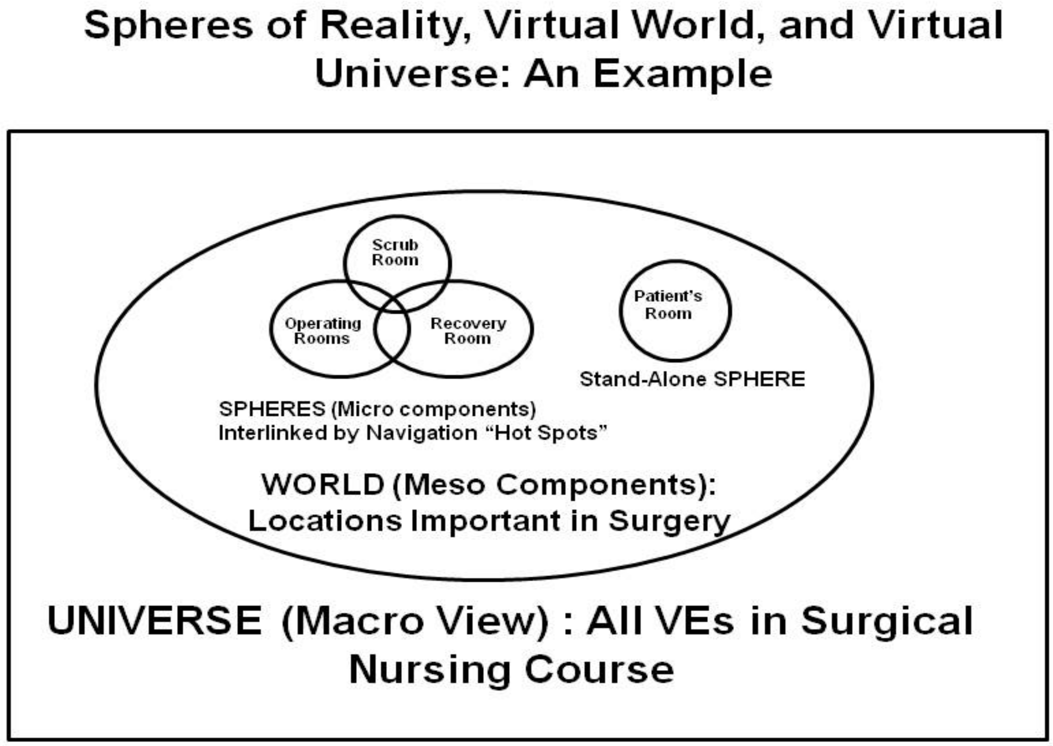

Figure 1. Example of spheres of reality (micro VE level), virtual world (meso VE level), and virtual universe (macro VE level) from a CTE surgical nursing curriculum.

a complex space full of often unfamiliar objects and spatial relationships. Throughout their exploration of the sphere, users must be able to maintain their own "egocenter" or sense of their own location (Blade & Padgett, 2002) and also both "egocentric" and "relative" frames of reference for objects and locations within the environment (Hunt and Waller). The Oklahoma State University VR research has clearly demonstrated that the skills required to comprehend this orientation; navigate the virtual environment; and maintain egocentric and relative orientations are very complex and require considerable training and practice. It is also possible that providing learners with some form of simple visual mapping device, such as a printed or side-screen digital layout map/diagram may be a valuable learning addition to an on-screen VE. This possibility merits specific experimental investigation in our future research.

To facilitate orientation, wayfinding, and actual navigation in a desktop sphere of reality, learners need to understand the physical nature of the VE in which they are immersed. On-screen VR movies have been described numerous times in Oklahoma State University research reports. As explained in these reports, these VEs can be panoramas (pans), objects, or mixed-mode scenes in which multiple pans and/or objects are combined and embedded, and are interlinked by clickable "hot spots." Pan movies can be either cylindrical with up to 360° horizontal sweep but limited vertical field, or spherical/cubic with 360° sweep both horizontally and vertically. Learner orientation in cylindrical and spherical VEs is illustrated in Figure 2. VR objects can be "picked up," zoomed in/out on, and "rotated" with the mouse on a single plane or multiple planes. Clickable hot spots can interlink multiple pans and embedded 3D objects, embedded

standard video clips, pop-up text, audio clips, or “doorways” to other entire spheres. Understanding these multiple exploration possibilities, the ways to move between linked spheres, and the software navigation devices and conventions that control them is another complexity for learners in desktop VEs that the Oklahoma State University research has demonstrated requires extensive pre-immersion training.

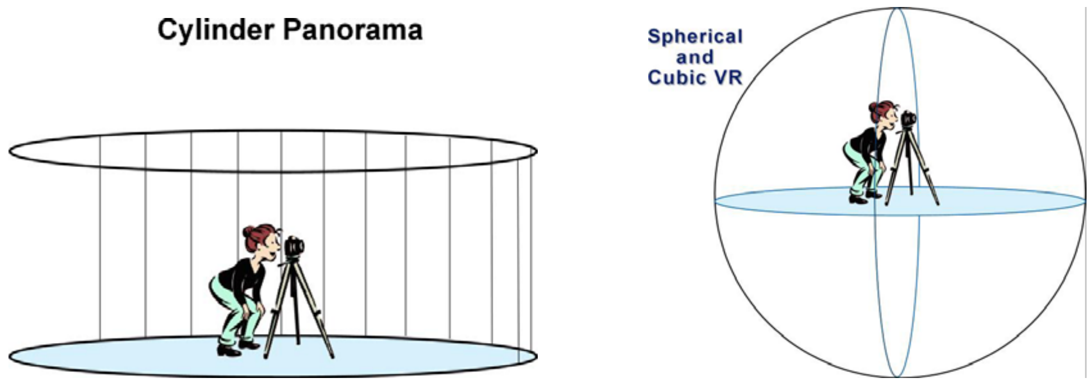

Figure 2. Learner orientation and egocentric viewpoint in cylindrical (left) and spherical (right) VEs.

Training and Preparing Learners for Experiencing CTE Spheres of Reality

Possibly the most critical conclusion from our research on VEs in CTE at Oklahoma State University is that learners must be systematically trained and prepared before they are exposed to a desktop VE. Our quantitative data from small-scale experiments with desktop VEs in CTE programs have suggested that this technology can be more effective than other training media, sometimes even with reasonable statistical effect sizes. However, item analyses of post-test questions about user orientation and object location in our VEs has indicted that the “lost in space” phenomenon, failure to navigate effectively, and a lack of understanding of the learning purposes and goals of VE exploration are frequent occurrences despite our efforts to prepare learners through basic navigation training and explanation of what they should accomplish in their VE exploration. This quantitative evidence has been strongly reinforced by many qualitative comments from our research subjects and field research team members.

Our general conclusion has been that learner preparation training must be far more extensive and be given much more time than we anticipated. To address this problem, we have developed the sphere of reality/virtual world/virtual universe conceptualization of CTE virtual instruction discussed above and a learner training process model. This training model is shown in Figure 3.

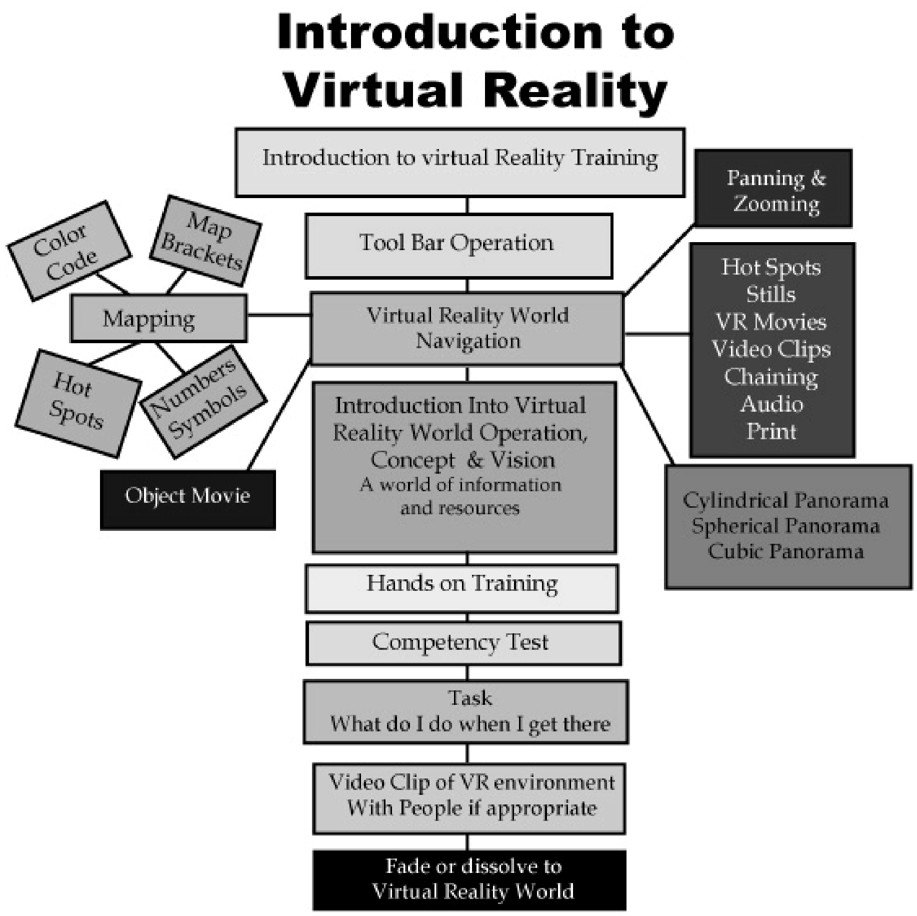

Figure 3. Ausburn training model for learner pre-immersion in CTE desktop virtual environments. Copyright 2009, Floyd B. Ausburn.

The Ausburn training model offers a training sequence to step learners through the components that our research indicates are critical to understanding: (a) the concept of a VE sphere of reality, (b) the relationships of individual spheres to broader virtual worlds and universes, (c) the components and types of virtual spheres and mapping devices they may need to navigate, and (d) the operation of desktop VR technology and its interfaces. Numerous checkpoints can be built into this training model for application of Hunter's (1982) Direct Instruction Model, with emphasis on giving learners feedback before, during, and after mastery of the VE concept and navigation. The Ausburn model also calls for verification of VR/VE mastery through use of a competency test, as well as clear definition of the learning goals of a VE immersion before allowing learners to enter and experience a virtual world. Refinement and application of this training model to the preparation of learners for VE environments is expected to become a major line of research for the Oklahoma State University VR research team and instrumental to our progress in this field.

Conclusion

With the development of sophisticated computers and digital imaging systems, virtual reality technologies and the virtual environments they create can now bring the learning benefits of complex VEs to the desktop at costs that are feasible for most schools and instructors. These technologies can offer dramatically expanded ways to teach and learn. The ability of these desktop VEs to take learners into situations that are difficult, dangerous, or impossible with other training technologies offers important advantages for many CTE programs where immersion in high-fidelity simulations of complex environments can help prepare learners to enter the workplaces they will soon encounter in the physical world.

However, a six-year research program in desktop VR for CTE at Oklahoma State University has demonstrated that to take full advantage of the benefits of screen-based VE training, learners require considerable pre-immersion training. Through this training, learners must understand the concept of VEs as spheres of reality that are complex and self-contained learning spaces full of a huge library of learning items and content that is all around them in 360°. They must also learn that individual spheres can be parts of larger virtual worlds and universes; that navigation devices are available to assist them in orienting and exploring in and among spheres; that these devices must be thoroughly mastered; and that exploration of virtual spaces has specific learning goals and expected outcomes.

This paper has discussed issues in creating "presence" in desktop VEs and preparing learners to successfully experience these learning environments. It has introduced a conceptualization of these VEs as spheres, worlds, and universes of reality, and has offered a training model for preparing learners for virtual experiences in CTE. The use of economically feasible desktop VR offers exciting learning opportunities for workplace preparation. Through application of the conceptualization and training model presented here, it may be possible to optimize this technology and extend its effectiveness and use in the wide variety of CTE programs that can benefit from "go there" immersive experiences for their students before they enter today's complex, expensive, and often dangerous working environments.

VEs with "presence" that succeed in immersing learners in high-fidelity reality simulation and giving them the illusion of actually "being there" are said to have the property of *presence*. Although much has been written about presence in VR, no one can yet clearly explain or document what creates it. At Oklahoma State University, six years of research with desktop VR/VEs has raised many questions and pointed the way to further research based on the principles and models presented in this paper. We believe these principles and models may guide the way to better understanding of what creates presence in VEs and maximizes their learning effectiveness. When virtual reality can create presence by accurately mirroring and effectively replicating physical reality and can prepare workers for what they will experience in the real world, CTE teachers, students, and employers will all be beneficiaries.

References

Ausburn, F.B., & Ausburn, L.J. (2008). Send students anywhere without leaving the classroom: Virtual reality in CTE. *Techniques, 83*(7), 43-46.

Ausburn, F.B., Ausburn, L.J., Cooper, J., Kroutter, P., & Sammons, G. (2007). Virtual reality technology: Current status, applications, and directions for education research. *OATE Journal: Oklahoma Association of Teacher Education, 11,* 7-14.

Ausburn, L.J., & Ausburn, F.B. (2004), Desktop virtual reality: A powerful new technology for teaching and research in industrial teacher education. *Journal of Industrial Teacher Education, 41*(4), 33-58.

Ausburn, L.J., & Ausburn, F.B. (2008a). New desktop virtual technology in technical education. *i-manager's Journal of Educational Technology, 4*(4), 48-61.

Ausburn, L.J., & Ausburn, F.B. (2008b). Effects of desktop virtual reality on learner performance and confidence in environmental mastery: Opening a line of inquiry. *Journal of Industrial Teacher Education, 45*(1), 54-87.

Ausburn, L.J., Ausburn, F.B., Steele, D., Kroutter, P., Dotterer, G., Washburn, E., Kisling, B., Williams, J., Nichols, A., & Fullbright, S. (2010). Critical elements for successful performance in desktop virtual reality environments. In *Proceedings of the 8th Annual Hawaii International Conference on Education.* Honolulu, HI.

Ausburn, L.J., Martens, J., Dotterer, G., & Calhoun, P. (2009). Avatars, pedagogical agents, and virtual environments: Social learning systems online. *i-manager's Journal of Educational Technology, 5*(4), 1-13.

Blade, R.A., & Padgett, M. L. (2002). Virtual environments standards and terminology. In K. M. Stanney, *Handbook of virtual environments: Design, implementation, and applications* (pp. 15-27). Mahwah, NJ: Lawrence Erlbaum Associates.

Bollman, B., & Friedrich, L. (n.d.). *Transfer of training in general V.R. environments.* Unpublished manuscript, Department of Information Technology and Electrical Engineering, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland.

Darken, R. P., & Peterson, B. (2002). Spatial orientation, wayfinding, and representation. In K. M. Stanney, *Handbook of virtual environments: Design, implementation, and applications* (pp. 493-518). Mahwah, NJ: Lawrence Erlbaum Associates.

Di Blas, N., & Poggi, C. (2007). European virtual classrooms: Building effective "virtual" educational experiences. *Virtual Reality, 11*(2-3), 129-143.

Hunt, E., & Waller, D. (1999). *Orientation and wayfinding: A review.* Unpublished manuscript, Department of Psychology, University of Washington, Seattle, WA. Retrieved from http://www.cs.umu.se/kurser/TDBD12/HT01/papers/hunt99orientation.pdf

Hunter, M. (1982). *Madeline Hunter's mastery teaching.* Thousand Oaks, CA: Corwin Press.

International Society for Presence Research. (2000). *The concept of presence: Explication statement.* Retrieved from http://ispr.info

International Society for Presence Research (2010). *About ISPR.* Retrieved from http://ispr.info

Isdale, J., Fencot, C., Heim, M., & Daly, L. (2002). Content design for virtual environments. In K. M. Stanney (Ed.), *Handbook for virtual environments: Design, implementation, and applications* (pp. 519-532). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Lombard, M., & Ditton, T.B. (1997). At the hearts of it all: The concept of presence. *Journal of Computer-Mediated Communication, 3*(2). Retrieved from http://www.ascusc.org/jcmc/vol3/issue2/lombard.html

Lombard, M., Ditton, T.B., & Weinstein, L. (2009, November). *Measuring presence: The Temple Presence Inventory.* Paper presented at Presence 2009: 12th Annual International Workshop on Presence. Los Angeles, CA. Retrieved from http://ispr.info

Mikropoulos, T.A. (2006). Presence: A unique characteristic in educational virtual environments. *Virtual Reality, 10*(3-4), 197-206.

Riva, G. (2003). Applications of virtual environments in medicine. *Methods of Information in Medicine, 42,* 524-534.

Riva, G. (2009). Is presence a technology issue? Some insights from cognitive sciences. *Virtual Reality, 13*(7), 159-169. doi: 10.1007/s10055-009-0121-6

Schroeder, R. (1997). Networked worlds Social aspects of multi-user virtual reality technology. *Sociological Research Online 2.* Retrieved from http://www.socresonline.org/uk/2/4/5.html

Selwood, I., Mikropoulos, T., & Whitelock, D. (2000). Guest editorial. *Education and Information Technologies, 5*(4), 233-236.

Seth, A., & Smith, S.S. (2004). PC-based virtual reality for CAD model viewing. *Journal of Technology Studies, 30*(4), 32-37.

Spagnolli, A., Lombard, M., & Gamberini, L. (2010). Editorial. *Virtual Reality, 14*(1), 1-2. doi: 10.1007/s10055-009-0152-z

Sunrise VR (2010). Welcome to learning in virtual reality. Retrieved from http://www.sunrisevr.com

Waller, D., Hunt, E., & Knapp, D. (1998). The transfer of spatial knowledge in virtual environment training. *Presence: Teleoperators and Virtual Environments, 7*(2), 129-143.

Watson, D. (2000). Editorial. *Education and Information Technologies, 5*(4), 231-232.

Winn, W., Hoffman, H., Hollander, A., Osberg, K., Rose, H., & Char, P. (1997, March). *The effects of student construction of virtual environments in the performance of high- and low-ability students.* Paper presented at the meeting of the American Educational Research Association, Chicago, IL.

Authors

Lynna J. Ausburn is an Associate Professor of Occupational Education Studies in the College of Education at Oklahoma State University, Willard Hall, Stillwater, OK, 74078. Email: lynna.ausburn@okstate.edu. Phone: 405-744-8322. **Floyd B. Ausburn** is adjunct faculty in Occupational Education Studies (specialist in advanced digital technologies) in the College of Education at Oklahoma State University, Willard Hall, Stillwater, OK, 74078. Email: fausburn@cimtel.net. Phone: 405-744-8322.